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SYSTEM AND METHOD FOR REMEDIATING PIPELINE BLOCKAGE

Background

[0001] In subsea petroleum recovery operations, pipeline systems are used to transport unprocessed and untreated petroleum production fluids from a petroleum reservoir in the sea bed to a production facility, or the like, floating on the surface of the sea.

[0002] If the production fluid, which usually includes water and gas, is not maintained above a threshold temperature, hydrates, wax and/or other types of compounds (hereinafter collectively referred to as "hydrates") will form which can cause blockage of the pipeline. Although the fluids come from the reservoir at a relatively high temperature, they will cool down when flowing through the subsea pipeline and especially when they sit in the pipeline when the flow terminates. In either case, the fluids can cool down below the above threshold temperature causing the hydrates to form.

[0003] This problem is exacerbated due to the fact that there is a relatively high head of liquid and fluid pressure in the pipeline that increase the value of the above threshold temperature to a value that is often greater than the temperature of the fluid in the pipe, thus increasing the chances of causing formation and maintenance of the hydrates in the pipe.

[0004] Therefore, what is needed is a cost-effective and efficient system and method for removing the hydrates from the pipeline.

Brief Description of the Drawings

[0005] Fig. 1 is an elevational view of a subsea petroleum operation including an embodiment of the invention.

[0006] Fig. 2 is an enlarged sectional view of a portion of the pipe of Fig. 1.

[0007] Figs. 3-6 are views, similar to that of Fig. 2, but depicting alternative embodiments.

Detailed Description

[0008] Referring to Fig. 1, the reference numeral 10 refers to a pipe that forms a riser and a flow line in a subsea petroleum recovery operation. The pipe 10 extends between a production facility 12 that floats on the surface of the sea S, and a tree system 14 extending just above a subsea well 16. Although the pipe 10 is shown curved in a manner to form an arc, it is understood that this is for the purpose of example only and that it can take other forms.

[0009] The tree system 14 is supported at the upper surface of the sea bed B and the well 16 extends into the sea bed for recovering petroleum based production fluid from a formation formed in the sea bed. The tree system 14 is conventional and, as such, includes a series of valves and associated components (not shown) for controlling the flow of the production fluid in the pipe 10. Thus, the production fluid flows from the well 16, through the tree system 14 and the pipe 10 and to the production facility 12 for further processing, under control of the tree system 14.

[0010] Although the production fluid from the well 16 is at a relatively high temperature, it will cool down when flowing through the pipe 10 and/or when it is confined in the pipe when the flow terminates. It will be assumed that the relatively high static head and fluid pressure in the pipe 10 causes the above threshold temperature, e.g., the temperature below which hydrates are formed, to be relatively high and that the temperature of the fluid falls below this threshold temperature therefore causing the hydrates to form in the pipe, as discussed above.

[0011] To remove the hydrates from the pipe 10 according to an embodiment of the invention shown in Fig. 2, the normal flow of production fluid from the well 16 and into the pipe 10 is terminated by closing the proper valves in the tree system 14 (Fig. 1), and a

section of coiled tubing 18 is installed in the pipe 10. In particular, the lower end of the tubing 18 is inserted into the pipe and lowered from a supply reel, or the like, at the production facility 12 until the latter end reaches a predetermined depth in the pipe, which corresponds to the depth sufficient to remove the head of liquid in the pipe, as will be explained. (Although the sections of the pipe 10 and the coiled tubing 18 are shown extending vertically in Fig. 2, this is for the purpose of illustration only since it is clear from Fig. 1 that other sections of the pipe 10 and the coiled tubing extend at an angle to the vertical.) The lower end of the tubing 18 extending in the pipe 10 is open and receives production fluid under conditions to be described.

[0012] An annular space 20 is formed between the outer diameter of the tubing 18 and the inner diameter of the corresponding section of the pipe, and continues to the production facility 12. Thus, production fluid from the well 16 accumulates in the tubing 18 and in the space 20 and creates a static head and a relatively high fluid pressure.

[0013] A supply of compressible, relatively low-density fluid, such as nitrogen or hydrocarbon gas, (hereinafter referred to as “gas”) from the production facility 12 is then introduced into the upper end of the space 20. The gas passes through the space 20 in a direction as shown by the arrows A which is in a direction towards the well 16, and is introduced at a pressure sufficient to displace the production fluid in the space.

[0014] The displaced production fluid is forced into the end of the tubing 18 as shown by the arrows B, before passing through the tubing in a direction towards the production facility 12 shown by the arrows C. During this movement, the original production fluid in the tubing 18 is also displaced. By the time the gas flowing down the space 20 reaches the end of the tubing 18, most of the production fluid is evacuated from the space 20 and the tubing 18 and passed to the production facility 12. The gas will then start flowing up the space 20 and the tubing 18 and carry any remaining production fluid with it.

[0015] Once most of the production fluid has been removed in the above manner, the supply of the gas to the space 20 is stopped, the system is depressurized either via the space and/or via the tubing 18. Thus, the remaining production fluids will be allowed to expand and flow naturally to the production facility by a variety of physical phenomena

including the expansion of the relatively low vapor pressure production fluid and/or the vaporization of the high vapor pressure gas.

[0016] It can be appreciated that this evacuation of the production fluid from the space 20 and the tubing 18 significantly reduces the static head and fluid pressure in the space and the tubing. This lowers the temperature of the fluid in the pipe to a value below the above-mentioned threshold temperature, and thus causes melting of the hydrates by the heat in the fluid and the surroundings, and the elimination of any blockage in the pipe 10.

[0017] After the above operation is completed, the tubing 18 can be removed from the pipe 10, and the normal flow of production fluid from the well 16, through the pipe 10 and to the production facility 12, can be restarted under control of the valves in the tree system 14.

[0018] The embodiment of Fig. 3 contains several components of the embodiment of Fig. 2, which are given the same reference numerals. It will be assumed that the relatively high static head and fluid pressure in the pipe 10 causes the above threshold temperature, e.g., the temperature below which hydrates are formed, to be relatively high and that the temperature of the fluid falls below this threshold temperature therefore causing the hydrates to form in the pipe, as discussed above.

[0019] To remove the hydrates from the pipe 10 according to the embodiment of Fig. 3, normal flow of production fluid from the well 16 and into the pipe 10 is terminated by closing the proper valves in the tree system 14, and the coiled tubing 18 is installed in the pipe 10 in the manner discussed above. A packer 26 is inserted into the space 20 to a desired depth and then set in place to seal against production fluid flow across it in a conventional manner and therefore isolate that portion of the space 20 extending above the packer from that portion extending below, as viewed in Fig. 3. This insertion of the packer 26 can be done in any conventional manner including installing the packer 26 on the lower end portion of the tubing 18 before it is installed in the pipe 10.

[0020] In this embodiment, the tubing 18 is kept void of production fluid during the above insertion of the packer 26 by maintaining a gas pressure on the tubing or by the use of a special check valve (not shown) that can be controlled by pressure variations in the tubing.

[0021] The gas in the tubing 18 is then vented to the production facility 12 (Fig. 1) or the above check valve is opened, causing the production fluid below the packer 26 to expand and flow upwardly in the tubing and to the production facility. This creates a gas/liquid interface in the pipe 10 that most likely will be somewhere in the tubing 18, with its position depending on the properties of the fluid, such as its vapor pressure and/or gas-to-liquid ratio.

[0022] The static head and fluid pressure in the pipe 10 is determined according to this height of the gas/liquid interface and the pressure of the gas above the interface. With the tubing 18 and the packer 26 in place and the tubing 18 depressurized in accordance with the above, the interface is likely to be lower than the original head in the pipe 10 before the tubing 18 and the packer are introduced, and thus the final equilibrium pressure in the pipe 10 will be lower.

[0023] The depth to which the tubing 18 and the packer 26 are inserted can be selected to ensure that the final equilibrium pressure is low enough to lower the temperature of the fluid in the pipe to a value below the above-mentioned threshold temperature, and thus cause melting of the hydrates by the heat in the fluid and the surroundings, and the elimination of any blockage in the pipe 10. After the above operation is completed, the tubing 18 and the packer 26 can be removed from the pipe 10, and the normal flow of production fluid from the well 16, through the pipe 10 and to the production facility 12, can be restarted.

[0024] The embodiment of Fig. 4 contains several components of the embodiment of Fig. 3, which are given the same reference numerals. According to the embodiment of Fig. 4, a submersible electric motor 30 is connected to the lower end of the tubing 18 and is operatively connected to a submersible pump 32.

[0025] It will be assumed that the relatively high static head and fluid pressure in the pipe 10 causes the above threshold temperature, e.g., the temperature below which hydrates are formed, to be relatively high and that the temperature of the fluid falls below this threshold temperature therefore causing the hydrates to form in the pipe, as discussed above.

[0026] To remove the hydrates from the pipe 10 according to the embodiment of Fig. 4, the normal flow of production fluid from the well 16 and into the pipe 10 is terminated

by closing the proper valves in the tree system 14, and the coiled tubing 18 is installed in the pipe 10 in the manner discussed above.

[0027] The motor 30 is activated to drive the pump 32 to lift the production fluid from that portion of the pipe 10 extending below the tubing 18, and pass the fluid through the tubing 18 and the pipe 10 to the production facility 12 (Fig. 1), as shown by the arrows A. Also, the pump 32 pumps the fluid from that portion of the space 20 extending below the packer 26, through the tubing 18, and to the production facility 12 (Fig. 1), as shown by the arrows B. As production fluid is pumped from the pipe 10 and the space 20 in the above manner, the packer 26 prevents the production fluid in the space 20 above the packer from flowing downwardly. Thus, the static head and the fluid pressure in the pipe 10 will be quickly reduced and the temperature of the fluid is lowered to a value below the above-mentioned threshold temperature, thus causing melting of the hydrates by the heat in the fluid and the surroundings, and the elimination of any blockage in the pipe 10. After the above operation is completed, the tubing 18, the packer 26, the pump 30 and the motor 32 can be removed from the pipe 10, and the normal flow of production fluid from the well 16, through the pipe 10 and to the production facility 12, can be restarted.

[0028] It is understood that the pump 30 and the motor 32 can be replaced by a hydraulic power turbine in which case separate conduits could be provided to convey the hydraulic production fluid supply, the hydraulic production fluid return and the fluid being removed from the pipe. Also, a length of flexible tubing could be installed on the suction end of the pump 30 to extend the reach of the production fluid removal capability of the system to some point significantly beyond the location of the pump. Also, the packer 26 can be eliminated and the fluid in the entire space 20 removed by the pump 32.

[0029] The embodiment of Fig. 5 includes components of the previous embodiments, which are given the same reference numerals. To remove the hydrates from the pipe 10 according to the embodiment of Fig. 5, the normal flow of production fluid from the well 16 and into the pipe 10 is terminated by closing the proper valves in the tree system 14 (Fig. 1), and two radially spaced, concentric coiled tubes 18a and 18b are installed in the pipe 10. The lower ends of the tubes 18a and 18b are inserted into the pipe 10 and lowered from a supply reel, or the like, at the production facility 12 (Fig. 1) until the

latter ends reach a predetermined depth in the pipe, which corresponds to the depth sufficient to remove the head of liquid in the pipe. (Although the sections of the pipe 10 and the tubes 18a and 18b are shown extending vertically in Fig. 5, this is for the purpose of illustration only since it is clear from Fig. 1 that other sections of the pipe 10 and the coiled tubes extend at an angle to the vertical.) The lower end of the tubes 18a and 18b extending in the pipe 10 are open and receive production fluid under conditions to be described.

[0030] As in the previous embodiments, a space 20 extends between the outer surface of the tube 18b and the inner surface of the pipe 10. Also, a space 36 is formed between the outer surface of the tube 18a and the inner surface of the tube 18b and extends to the production facility 12. Thus, production fluid from the well 16 accumulates in the tubes 18a and 18b and in the space 36 and creates a static head and a relatively high fluid pressure.

[0031] A packer 26 is lowered into the space 20 to a desired depth and then set in place to seal against production fluid flow across it in a conventional manner and therefore isolate that portion of the space 20 extending above the packer from that portion extending below, as viewed in Fig. 3.

[0032] A supply of compressible, relatively low-density fluid, such as nitrogen or hydrocarbon gas, (hereinafter referred to as "gas") from the production facility 12 is then introduced into the upper end of the space 36. The gas passes through the space 36 in a direction as shown by the arrows A which is in a direction towards the well 16, and is introduced at a pressure sufficient to displace the production fluid in the space.

[0033] The displaced production fluid is forced into the end of the tube 18a as shown by the arrows B, before passing through the latter tube in a direction towards the production facility 12 shown by the arrows C. During this movement, the original production fluid in the tube 18a is also displaced. By the time the gas flowing down the space 36 reaches the end of the tubes 18a, most of the production fluid is evacuated from the space 36 and the tube 18a and passed to the production facility 12. The gas will then start flowing up the space 36 and the tubes 18a and 18b and carry the production fluid with it.

[0034] The cross section of the flow path through the space 36, as well as the flow path defined in the interior of the tube 18a, is significantly smaller than the diameter of the pipe 10. This promotes the lifting of the production fluid up the tube 18a and the space 36 in accordance with the above.

[0035] Once most of the fluid has been removed in the above manner, the supply of the gas to the space 36 is stopped, the system is depressurized either via the space or the tubing and the remaining production fluid allowed to expand and flow naturally to the production facility 12 via the tubes 18a and 18b by a variety of physical phenomena including the expansion of the relatively low vapor pressure production fluid and/or the vaporization of the high vapor pressure gas.

[0036] It can be appreciated that this evacuation of the production fluid from the space 36 and the tubes 18a and 18b in the foregoing manner significantly reduces the static head and fluid pressure in the space and the tubing. The reduction of the static head and fluid pressure in the pipe 10 lowers the temperature of the fluid in the pipe to a value below the above-mentioned threshold temperature, and thus causes melting of the hydrates by the heat in the fluid and the surroundings, and the elimination of any blockage in the pipe 10. After the above operation is completed, the tubes 18a and 18b and the packer 26 can be removed from the pipe 10, and the normal flow of production fluid from the well 16, through the pipe 10 and to the production facility 12, can be restarted.

[0037] The embodiment of Fig. 6 contains several components of the embodiment of Fig. 2, which are given the same reference numerals, and, as in the previous embodiments, it will be assumed that production fluid is present in the tubing 18 and in the space 20 between the tubing 18 and the pipe 10. It will be assumed that the relatively high static head and fluid pressure in the pipe 10 causes the above threshold temperature, e.g., the temperature below which hydrates are formed, to be relatively high and that the temperature of the fluid falls below this threshold temperature therefore causing the hydrates to form in the pipe, as discussed above.

[0038] To remove the hydrates from the pipe 10 according to the embodiment of Fig. 6, the normal flow of production fluid from the well 16 and into the pipe 10 is terminated by closing the proper valves in the tree system 14, and the tubing 18 is installed in the

pipe 10 in the manner discussed above. One or more conventional pigging devices 40 are then inserted downwardly into the space 20 through the column of production fluid in the space. This insertion can be done in any conventional manner including installing the pigging devices 40 on the lower end portion of the tubing 18 before it is inserted in the pipe 10.

[0039] The pigging devices 40 are configured to normally allow fluids to flow past them in the space 20, but can be expanded to bridge across the space 20 in a conventional manner, thus creating a dynamic seal. It will be assumed that the pigging device 40 nearest to the production facility 12 (Fig. 1), which is the uppermost device as viewed in Fig. 6, is expanded and the remaining devices are configured to allow fluid to flow past them.

[0040] Gas from the production facility 12 is then introduced into the upper end of the tubing 18 and flows in the tubing in a direction shown by the arrows A, which is towards the well 16. The gas displaces the production fluid in the tubing 18 which exits the lower end of the tubing, and flows in the space 20 in a direction shown by the arrows C, which is towards the production facility 12. Thus, the displaced fluid and the gas flowing through the space 20 in the above manner will pass through all of the pigging devices 40 with the exception of the above device nearest to the production facility which will be pushed upwardly in the space by the gas and fluid. As the latter pigging device 40 moves upwardly, it will sweep out the fluids above the space 20. The remaining pigging devices 40 can be expanded as necessary and forced towards the production facility 12 in the above manner to remove the desired quantity of production fluid from the pipe.

[0041] Once the production fluid has been removed from the space 20 in the above manner, the supply of the gas is stopped, the system is depressurized either via the space or by the tubing 18. The remaining production fluid is allowed to expand and flow naturally to the production facility 12 via the tube 18 or by the space 20 by a variety of physical phenomena including the expansion of the relatively low vapor pressure production fluid and/or the vaporization of the high vapor pressure gas. After the level of production fluid is at or below the desired level, the pipe 10 can be further depressurized if desired by flowing the gas down the space 20 and upwardly through the tubing 18.

[0042] The reduction of the static head and fluid pressure in the pipe 10 lowers the temperature of the fluid in the pipe to a value below the above-mentioned threshold temperature, and thus causes melting of the hydrates by the heat in the fluid and the surroundings, and the elimination of any blockage in the pipe 10. After the above operation is completed, the tube 18 and the pigging devices 40 are removed from the pipe 10, and the normal flow of production fluid from the well 16, through the pipe 10 and to the production facility 12, is restarted.

Variations

[0043] It is understood that variations may be made in the foregoing without departing from the scope of the invention. For example, although the pipe 10 and the tubing 18 are shown extending vertically in Figs. 2-6 for the purpose of example, it is understood that they also can extend at an angle to the vertical. Hence, spatial references, such as “up”, “down”, “upper”, “lower”, “upwardly”, “downwardly”, etc. are for the purpose of illustration only and do not limit the specific orientation or location of the pipe and tubing. Also, the general shape of the pipe extending between the facility 12 and the tree system 14 can vary from the form of the example of Fig. 1. Further, the above embodiments are not limited to the flowing of production fluid from a well, but are equally applicable to the flow of any type of fluid from a well to a remote location. Still further, the space 20 does not necessarily have to be annular.

[0044] Although only a few exemplary embodiments of this invention have been described in detail above, those skilled in the art will readily appreciate that many other modifications are possible in the exemplary embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention as defined in the following claims. In the claims, means-plus-function clauses are intended to cover the structures described herein as performing the recited function and not only structural equivalents, but also equivalent structures.